Development and Application of an Irrigation Ontology

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Abstract

An ontology consisting of approximately 250 concepts and 300 relationships was constructed in the domain of irrigation. More specifically, the domain covers extension information and educational materials aimed at teaching small scale farmers basic principles of irrigation. The methodology used for constructing the ontology is presented. The top-level concepts in the domain ontology along with details and examples of concepts and relationships in the irrigation domain are also described. The ontology was created using on-line tools. These tools provide complete database management facilities for the ontology and educational content associated with concepts in the ontology including text, images, and other graphic elements. The database content is automatically converted into conventional Web pages and other formats to create educational materials on demand.

Key words: Ontology, Irrigation, Extension, Methodology, Modelling

1 Introduction

Ontologies offer ways of better managing the vast educational resources that have been and are still being developed by organizations such as the Cooperative Extension Service and United Nations Food and Agricultural Organization. Issues involved in educational resource management include property identifying (cataloging) each resource, where large numbers of resources exist at many levels of granularity ranging from entire training curriculums to individual lessons or modules to the content of those modules including individual text fragments, images, and other multimedia resources. New authoring tools for generating this content in the context of ontologies, and tools for automatically generating presentations in different formats from shared content are needed. Learning object technologies and standards such as SCORM [Godwin-Jones 2004] address ways of better packaging educational resources into reusable components. SCORM provides a metadata standard for describing learning objects, and includes tags that can reference taxanomic subject classification systems including ontologies (although SCORM itself is not a standard for ontologies). Content management systems are database mangaement systems for storing content in the form of text and other multimedia resources, store content in a presentation-independent way, and are capable of generating particular presentations from content according to different customizable styles. Combining content mangaement systems with ontologies and with learning object standards leads to an ontology management system that can better organize educational content, facilitate content development, and automate the process of generating educational materials. By using ontologies the information publishing process can be greatly facilitated [Clark, et al 2004].

This approach is being used at the University of Florida on a range of project, including one on developing educational extension materials to assist farmers with limited formal education to understand basic principles of irrigation. These materials rely heavily on graphic images to illustrate irrigation principles such as creation of water retention devices or general layout of irrigation systems (text is limited or optional because many of the farmers using these materials are illiterate). Furthermore these materials must be adapted to fit local cultural environments. For example, illustrations should changed to show crops local to the area where they are applied, and people should be presented in gender and culturally specific contexts.

Water management and irrigation is a major component in agricultural technology. Currently no known ontology on irrigation exists. An irrigation ontology was constructed to provide a framework for organizing materials within this specific domain. It can also act as a starting point for a larger ontology covering irrigation concepts in general. This paper presents the methodology we used to construct the irrigation ontology, briefly describes the tools and environment used to construct the ontology, and provides details of the resulting irrigation ontology including the top-level concepts, and some examples of small domains within the ontology. A complete list of the concepts appearing in the ontology is included in the appendix.

Using an ontology management system, the ontology is the basis of a fully operational database management system [Beck 2005]. The concepts and relationships in the ontology also contain primitive data such as text, images, and other multimedia resources that provide additional definition of the concepts. The ontology management system includes a formally defined ontology language which also acts as a data modeling (data definition) language for the database, tools for inspecting and editing the ontology, operations for manipulating the ontology (reasoners), and secondary storage management to support efficient processing of these operations. We used an ontology manager to construct the irrigation ontology along with associated educational content for our domain. Facilities that are part of this system for automatically generating presentations from content are used to create Web-based and printed educational materials. This process is described below.

2 Objectives

This paper presents an irrigation ontology to support development of educational resources aimed at teaching introductory irrigation concepts to a multicultural audience. However, the process of building the irrigation ontology is an important first step in facilitating shared ontologies for this domain. By publishing the irrigation ontology within the framework of the Agricultural Ontology Service [AOS 2005], it is hoped that others working in this area can benefit from and build on the work presented here. The process of building working ontologies is still in its infancy. Although established standards for building ontologies now exist, and formal methodologies are well developed, there is a need to build working examples and demonstrate their utility.

The technology for content management, learning objects, and authoring tools for creating educational resources likewise is in a rapid state of evolution. Conventional tools (Microsoft PowerPoint, Adobe Acrobat, and Macromedia Breeze) while widely used do not attempt to represent content in a presentation independent format, and make no attempt at classifying content in any context, let alone one as sophisticated as an ontology. By building educational materials within an ontology management system, we hope to show the advantages of this approach to better organize educational resources, and gain flexibility in automatically presenting educational materials to meet individual learning styles, native languages, and respect local cultural contexts. This paper presents a framework and example for developing materials in such a way. We demonstrate the use of an ontology for managing and storing content for educational materials in the irrigation domain, show that the creation of an irrigation ontology will allow greater shareability and reusability of extension information resources, permitting more flexibility in the production of educational materials, and finally, develop on-the-fly educational materials based on the irrigation ontology's content.

3 Materials and Methods

3.1 Methodology Used to Build the Irrigation Ontology

A detailed explanation of an ontology development process can be found in Noy and McGuiness [2001]. In general an ontology development methodology includes the following steps [Noy and McGuiness 2001; Prieto-Diaz 2002]:

- Define the domain, objectives, and scope of the ontology
- Enumerate important terms within the ontology's domain
- Define the hierarchy of the terms

- Define the relationships (and type of relationship) among the terms
- Define a concept for each term, and/or its properties

It it is important to clarify that any ontology has to have a finite scope and purpose for its content. It is important to recognize that the final application defines the domain of the ontology. The main use for this ontology will be for the creation of educational educational materials for small farmers. The Irrigation Ontology was also limited to practical irrigation concepts rather than theoretical ones. Finally limits where imposed by available time and labor. By having these factors in mind the ontology development process can be guided toward those objectives.

The modeling methodology aims at representing the "real world" in logical terms using a given ontology software editor, in this case ObjecEditor. A list of the term relevant according to the objectives of the ontology was developed with information extracted from many sources such as the Land and Water Development Division of the Food and Agricultural Organization [LWD 2005], American Society of Agricultural Engineering (ASAE) [ASAE 2005], United States National Agricultural Library Thesaurus (NALT) [NATL 2005], and the Extension Data Information Source (EDIS) from the University of Florida [EDIS 2005]. A group of specialists from the University of Florida was also involved in the knowledge modeling process. It is important to mention that every individual has a personal ontology; meaning that each one has a particular perception of the knowledge in a given domain. In order to create a common ontology from the perceptions of individual experts, much group discussion is required to arrive an agreed meaning for terms.

The irrigation ontology modeling methodology follows a top-down approach [Prieto-Diaz 2002]. This means that the more general terms are placed higher in the hierarchy, and from them the terms start getting more specific towards the lower levels of the ontology. After following classifications present in most publications, some of the terms where placed at a given level by agreement between the experts involved in the modeling of the irrigation ontology. Nevertheless, the process of selecting the terms, its definitions, and then determine the relation among those concepts was iterative, meaning that the process had to be repeated multiple times until all the experts agreed on a common irrigation ontology. For other concepts the classification process was much simpler, having only to follow pre-existing classifications.

3.2 ObjectEditor

The Irrigation Ontology was constructed using ObjectEditor a graph-based, Web-based tool for constructing ontologies within specific domains developed at the University of Florida, USA. ObjectEditor can be run on-line in any Web browser (utilizing a Java plug-in) that communicates to a remote server hosting an object-oriented database management system (ObjectStore). The ontology and the database are capable of organizing, storing, and searching content more efficiently than a traditional system. ObjectEditor's interface enables users to interact with the ontology in order to define content objects and represent how the objects in a domain are interrelated. ObjectEditor provides a complete ontology management system for editing, viewing, managing physical storage, managing multiple users, and providing reasoning and query processing facilities.

In the irrigation ontology the concepts are represented as classes. Each class can have multiple properties, ObjectEditor supports simple string, rich text, integer, float, range, and images, as data types for the properties. Associations represent relationships between objects. All the subclasses inherit the properties and associations of their superclasses. Each class has a short description or *gloss*. This facilitates the definition of the sense of each concept. For the irrigation ontology, the main irrigation related topics (terms) selected are: Irrigation Water Sources, Weather, Plant, Soil, Drainage, Irrigation System Design, Irrigation System Management, and Irrigation Equipment and Structures (Fig. 1).

ObjectEditor allows the creation of "modules" that permit the division of the ontology in subareas; this permits a less cluttered, more focused presentation of the terms and relationships in the ontology. Modules are only a visualization tool available in ObjectEditor; modules are not part of the ontology modeling language. Not all these modules contain the same number of related terms nor they have the same level of detail. The Irrigation System Design, Irrigation System Management, and Irrigation Systems and Structures modules have in average more terms and detail than the others. This again corresponds to the objectives of the ontology. However, the other topics (modules) are included because they are needed to give better sense to the ontology. At this time the Irrigation Ontology consists of more than 250 terms, and around 300 relationships among those terms (see appendix).

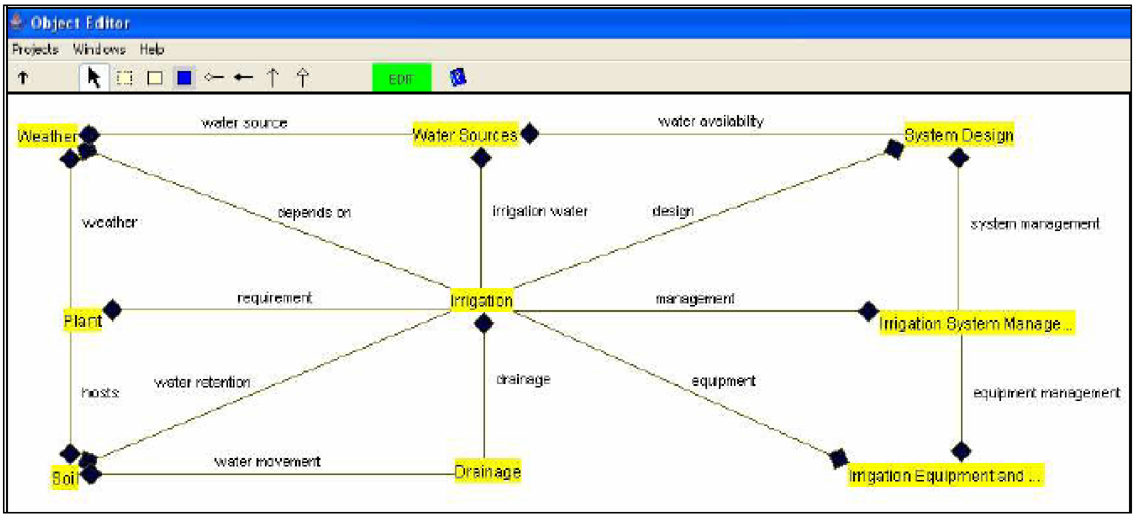


Fig.1 Main topics covered by the Irrigation Ontology in ObjectEditor

ObjectEditor provides four types of relationships: generalization, sequence, part-of, and association. Generalization is used to represent superclass/subclass relationships. Part-of is used to for objects that are physically a part of larger composite objects. Sequence is used to indicate that a concept follows another. Association is used between two otherwise related concepts. These different relationships are graphically represented in ObjectEditor by different types of vectors. Most of there relationships are presented in Fig. 2, with dashed-line rectangles. Apart from the knowledge modeling that the irrigation ontology represents, ObjectEditor allows the storage and management of content. Content can include text, graphics, and mathematical equations. Then this content can be render in multiple formats depending on the method of presentation. For example, Web pages for personal computers, and PDA's, and files (i.e., pdf) for printed media. The separation of content from format increases the flexibility at publication time, reducing time and work needed to reproduce the same content in different media.

4 Results

4.1 Irrigation Ontology Modelling

Figure 2 presents a section of the irrigation ontology that represents the "system design". For example, this section represents the "conveyance system" and its subclasses "ditch" and "pipeline" are joined by a generalization relationship.

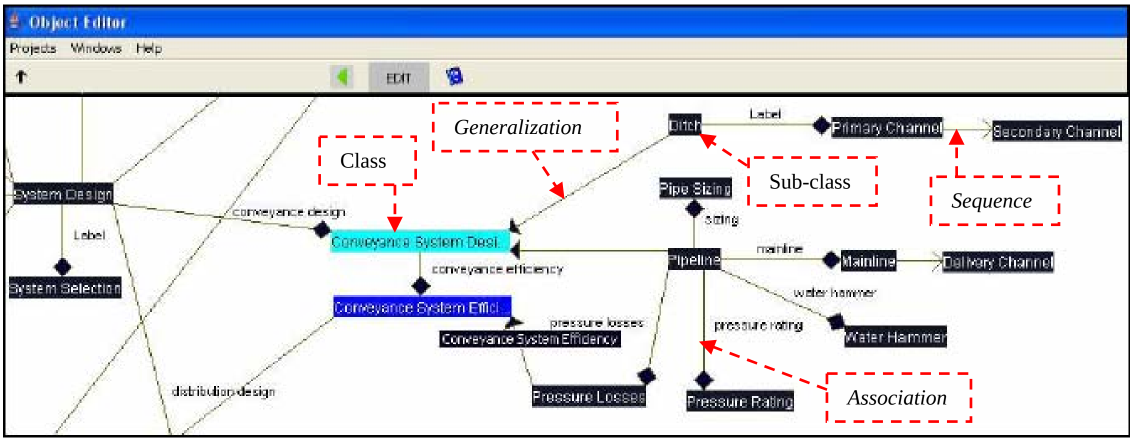


Fig.2 Section of the Irrigation Ontology as presented in ObjectEditor

Also shown in Figure 2 is that the “conveyance system design” has a “conveyance system efficiency”. The concept “pipeline conveyance system” is a subclass of “conveyance system”, having associations “pressure losses”, a “pressure rating”, and “water hammer”, it could also have a “main line” and a “delivery channel”. More detailed relationships indicate that a “delivery channel” has to follow a “main line”. In another example of a sequence, a primary channel is followed by a secondary channel, and secondary channel by a distribution channel, in that order. In a real irrigation project the secondary channel can only be present after a primary channel, and a delivery channel should go after a secondary channel, and that is the form presented in Fig. 3. Nevertheless, a delivery channel can sometimes go directly after a primary channel.

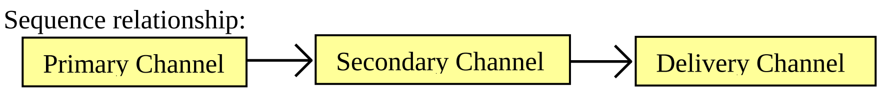


Fig.3 Use of the part-of and generalization relationships in the Irrigation Ontology

Often concepts need clarification. Using the concept “precipitation” as the surce of water directly available to the plant is erroneous. However “precipitation” includes rain, snow, and hail, and of these three concepts only rain is the precipitation that is directly available to the plant.

Improper placement of concepts within the ontology will adversely affect the sense and functionality of the ontology. As an example, the water resources topic contains the concepts surface water, ground water, and harvested water. In the first design all these terms where first related through an association with conveyance system and then to the water resources class. In the current design surface water, ground water, and harvested water are considered subclasses of water resources. Conveyance system was moved to the irrigation system design topic where it is related to pumping system and distribution system (Fig. 4).

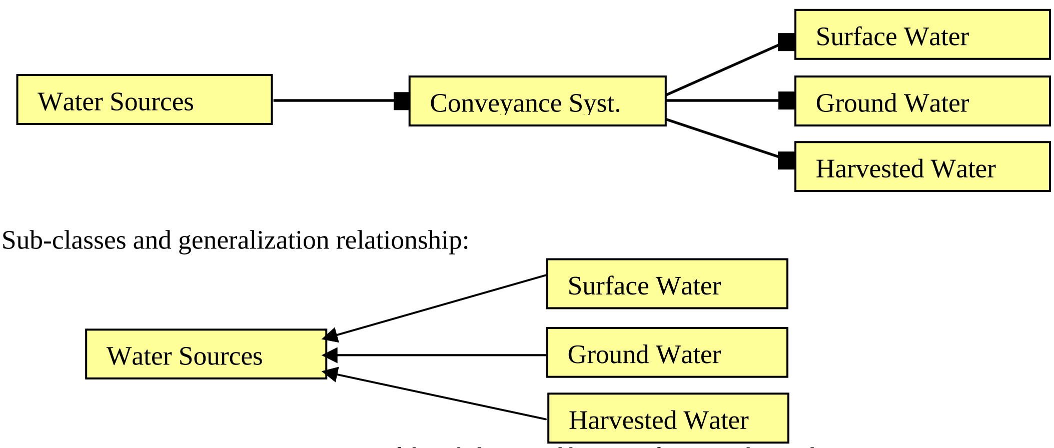


Fig.4 Use of the subclasses and location of terms in the ontology

As another example, originally the “irrigation system design” concept included concepts related to system selection and equipment selection. System design includes concepts like terrain conditions, soil characteristics, crop requirements, and others. All these factors will influence the choice of system and are used in the calculations involved in the irrigation system design. After including all those terms it was decided that equipment selection was related to irrigation system design, but it would be better located within the irrigation equipment topic.

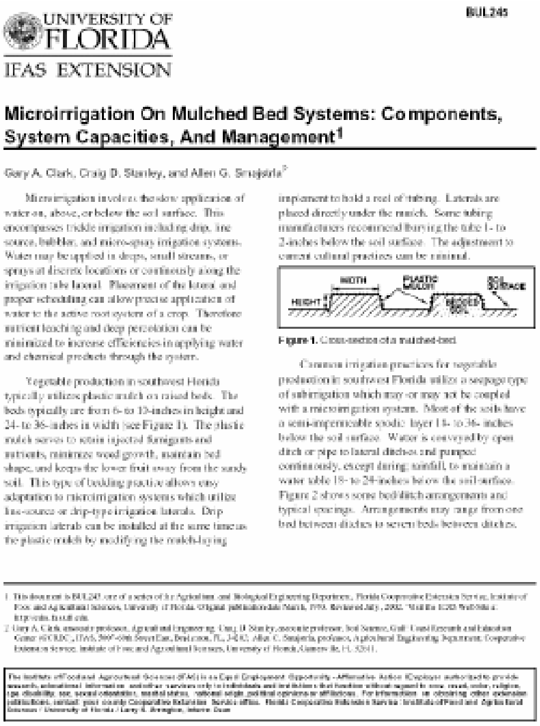
4.2 Presentation Generation

The ontology management system used to create the irrigation ontology also stores content (multimedia content in the form of text, images, sound, video, and other content) associated with each ontology concept. Thus it provides content management with the ontology acting to integrate the content. The content also enhances the concept definitions (although not compatible with and essentially ignored by the reasoner, such content provides useful annotations).

Presentations can be automatically generated from this content by specifying a mapping from content objects to the desired presentation. This mapping, which can be implemented using XSL style sheet technology, specifies how content objects are to appear (for example, fonts and colors) and also manages policies on how they can be arranged. Mappings can generate presentations in a variety of different Web page styles, slide show formats (such as PowerPoint) and printed layouts (such as PDF or EPS formats).

A sample for a printed publication on irrigation appears in Figure 5, and a sample of a slide-style presentation appears in Figure 6. The elements in the printed publication were created using XML FO (Formatting Objects) and a commercial rendering package, RenderX [RenderX 2004]. The process involved 1) generate an XML document from the content for the publication stored in the ontology manager, 2) convert the XML source document to an XML FO based on style specified in an XML style sheet (XSLT), and 3) rendering the XML FO to a printable publication (PDF format) using RenderX.

The approach to the graphics example in Figure 5 is to store elements of the graphic image using vector graphics. The vectors are stored in the ontology management system as database objects. Larger graphics are composed from smaller elements, much like image libraries in conventional graphics packages. However, the ontology is used to enhance the description of the graphic elements. The not only improves search and retrieval of specific elements, but enables localization at the level of concepts. For example, graphic elements appearing in Figure 6 can be changed based on crops grown in a particular local, and people can appear differently (race, gender, and cloathing can change) based on local conditions. In other software environments (such as Scalable Vector Graphics) these features must be changed at the level of individual graphic primitives (lines, polygons) but in the ontology management system these primitive elements are given meaning as objects (a plant, a crop, a person with a particular skin color).



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BUL245

Microirrigation On Mulched Bed Systems: Components, System Capacities, And Management[1]

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Microirrigation involves the slow application of water on, above, or below the soil surface. This encompasses trickle irrigation including drip, line source, bubbler, and micro-spray irrigation systems. Water may be applied in drops, small streams, or sprays at discrete locations or continuously along the irrigation tube lateral. Placement of the lateral and proper scheduling can allow precise application of water to the active root system of a crop. Therefore nutrient leaching and deep percolation can be minimized to increase efficiencies in applying water and chemical products through the system.

Vegetable production in southwest Florida typically utilizes plastic mulch on raised beds. The beds typically are from 6- to 10-inches in height and 24- to 36-inches in width (see Figure 1). The plastic mulch serves to retain injected fumigants and nutrients, minimize weed growth, maintain bed shape, and keeps the lower fruit away from the sandy soil. This type of bedding practice allows easy adaptation to microirrigation systems which utilize line-source or drip-type irrigation laterals. Drip irrigation laterals can be installed at the same time as the plastic mulch by modifying the mulch-laying implement to hold a reel of tubing. Laterals are placed directly under the mulch. Some tubing manufacturers recommend burying the tube 1- to 2-inches below the soil surface. The adjustment to current cultural practices can be minimal.

Figure 1. Cross-section of a mulched-bed.

Common irrigation practices for vegetable production in southwest Florida utilize a seepage type of subirrigation which may or may not be coupled with a microirrigation system. Most of the soils have a semi-impermeable spodic layer 18- to 36- inches below the soil surface. Water is conveyed by open ditch or pipe to lateral ditches and pumped continuously, except during rainfall, to maintain a water table 18- to 24-inches below the soil surface. Figure 2 shows some bed/ditch arrangements and typical spacings. Arrangements may range from one bed between ditches to seven beds between ditches.

Fig.5 Example of print file generated from the ontology management system.

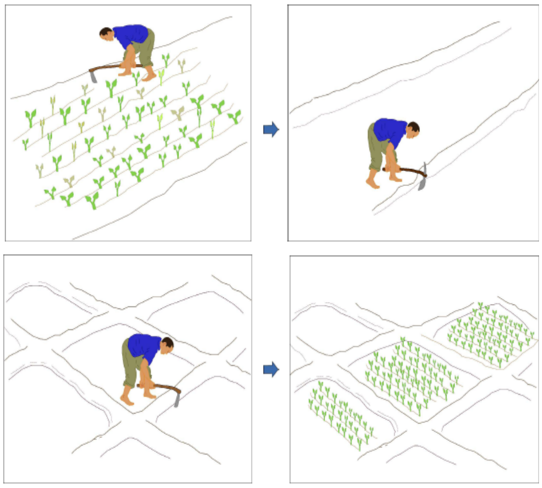

Fig.6 Example of educational drawings on irrigation techniques

5 Conclusions

The irrigation ontology acts as a database for organizing and storing content. One of the uses for this ontology is for organizing information consisting of documents, images, and other media. The irrigation ontology and database are used for physical storage, manipulation of content objects and relationships. The irrigation ontology provides a conceptual map to which media can be attached and which people can navigate to find information. Other advantages of incorporating an ontology include better ways of representing concepts, ability to support natural language-based references to objects, graphic browsing based on data visualization of ontologies, and ontology assisted search.

The application presented here can automatically generate educational materials in a variety of different styles. The application can generate presentations on-the-fly for any topic in the irrigation domain based on queries. Future work will include utilizing multilingual support incorporated into the ontology manager for naming concepts and for all text content in several different languages.

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7 Appendix

List of Terms Included in the Irrigation Ontology

Weather: wind, radiation, temperature, precipitation, evapotranspiration, transpiration, evapotranspiration methods, Pan, Penman-Monteith, Blanney-Criddle, crop coefficient, pan coefficient.

Plant: leaf, stem, root, root depth; plant type, planting system, spacing; growth season, growth stage, phenological stages, nutrient requirement, climatic requirement, cold resistance, toxicity resistance, salinity resistance.

Soil: soil chemistry: sodicity, salinity, soil pH, nutrients, electric conductivity; topography: erosion, wind, water, water movement; soil available water: field capacity, permanent wilting point; structure: bulk density, compaction; soil moisture retention: mulch, cover crop, conservation tillage; texture: clay, sand, silt, loam; organic matter, permeability: hydraulic conductivity, infiltration.

Water Sources: water quantity, water quality, reclaim water, municipal sources; surface water, water bodies: lake, river, reservoir; groundwater: unsaturated, saturated; aquifer: confined, unconfined, artesian well, well; root zone: hygroscopic water, capillary water; cost, slope, soil, harvested water: basin wide harvesting, macro-catchment, floodwater; on-farm water harvesting: rooftop, micro-catchment: natural depressions, natural rock dams, retention ditch, planting pit; contour farming: stone lines, terrace, bund, semi-circular, ridge, triangular; earth basin: meskat, negarim.

Drainage: drainage design: collector ditches, tile drainage, lateral ditches, perimeter ditch & dike, beds & water furrows, drain tile clogging; drainage considerations: spacing, alignments, drain depth, drain capacity, outlets, connections; flooding damage, summer/winter time intervals; drain clogging, ochre depositions, sulfur slimes.

System Design: site characteristics, irrigation system layout: spacing, planting system; economic considerations, system uses: crop cooling, freeze protection, irrigation requirement: crop requirement, system requirement: leaching requirement, system efficiency; drainage, system selection, pumping system design: pumping equipment, pumping equipment selection; pumping system efficiency; conveyance system design: ditch, primary channel, secondary channel, pipeline, main line, delivery channel, pipe sizing; water hammer, pressure rating, pressure losses, conveyance system efficiency; distribution system design, distribution system efficiency: gravity irrigation, seepage irrigation, seepage irrigation efficiency, surface irrigation, surface irrigation efficiency; pressurized irrigation, pressurized irrigation efficiency.

Irrigation System Management: irrigation scheduling: timing of irrigation, rainfall measurement, field water budget, soil moisture monitoring; scheduling methods: visual appearance of the plant, water budget, long-term average irrigation requirements, climatic data, direct measurement, soil moisture sensor; irrigation system maintenance: check pump: pressure settings, parts, lubrication; surface irrigation, clean canals; pressurized irrigation: check lines for leaks, clean lines or pipes, clean filters, uniformity test, irrigation system calibration; chemigation: volumetric flow rate measurement, calibration of injection systems, calculating fertilizer injection rates.

Irrigation Equipment and Structures: system control: flow meter, pressure gauge, valve: gate valve, ball valve, vacuum regulator, pressure regulator, automatically controlled valve; filtration equipment: cartridge filter, media filter, disc filter, screen filter, centrifugal filter; conveyance equipment, pipeline, pipe fittings: adapter, coupling, cross, elbow, tee, plug; distribution equipment: sprinklers, guns, emitter: microsprinklers, drippers, bubblers; pumping equipment: dynamic pump, positive displacement pump: reciprocating pump: piston pump, diaphragm pump; rotary pump: flexible impeller pump, vane pump, lobe pump, gear pump, screw pump; chemigation equipment: backflow prevention, chemical flow meters, pressurized mixer tanks; chemical injection equipment: suction side injection, venturi injectors; system controllers: computer controller, soil moisture sensors: TDR, dielectric sensors, neutron probe, resistance blocks, tensiometer.